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Mission Highlights STS-82

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Five space walks to update an old friend

Commander Ken Bowersox summarized to the world the feelings of Mission Specialist Steve Hawley and the rest of the crew upon the grapple of the Hubble Space Telescope. “You should have seen the expression on Dr. Stevie’s face,” said Bowersox with the telescope firmly in the grasp of the robot arm. “It looked like he just shook hands with an old friend.”

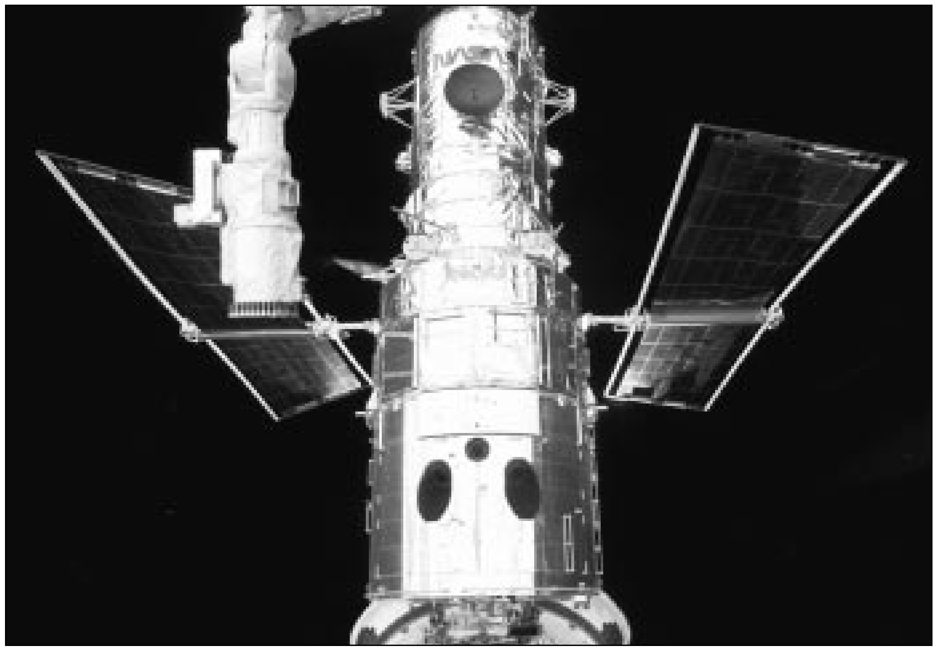
The STS-82 mission marked the second servicing mission to update or replace instruments aboard the Hubble Space Telescope.

Discovery’s astronauts gave high praise to the instrument they worked on and the teamwork that made the mission a success.

“STS-82 is over, but the mission of Hubble goes on,” Hawley said. “Hopefully it will go on for months, years, maybe decades enabled by subsequent servicing missions. In those years, Hubble will revolutionize our understanding of the universe and will answer questions that previously we thought were unanswerable… I want everyone that contributed to this mission to feel a part of that understanding.”

Commander Ken Bowersox said the mission was a success because the crew worked so well with the team on the ground.

“I was proud to watch my guys work out there in the payload bay,” he said. “It is important to remember that we were doing something more than servicing the best telescope in the universe. We were learning how to live and work in space. It is the same thing we will be doing on the space station



The Hubble Space Telescope after capture, berthed on the flight Support System (FSS) in Space shuttle *Discovery*’s payload bay.

Space Shuttle *Discovery*

February 11-21, 1997

Commander:	Ken Bowersox
Pilot:	Scott Horowitz
Payload Commander:	Mark Lee
Mission Specialist:	Joe Tanner Steve Hawley Greg Harbaugh Steve Smith

Astronaut Steve Hawley at controls for the Remote Manipulator System during the third EVA.

and every time we send people into orbit, we are laying the ground work for the future.

Mission Events

The second servicing mission for the Hubble Space Telescope (HST) got underway with a 2:55 a.m. CST launch of the Space Shuttle *Discovery* on February 11, 1997.

The first few days of the flight were spent preparing for the retrieval of HST by checking out the shuttle's robot arm, surveying the payload bay work sites and testing the space suits that were used for the four planned space walks. In addition, the Commander Bowersox and Pilot Horowitz conducted rendezvous maneuvers designed to adjust *Discovery*'s closing rate on the HST so the shuttle would arrive about 2,400 feet below Hubble an hour before its scheduled retrieval.

Discovery's astronauts used the remote manipulator system to grapple Hubble at 2:34 a.m. CST on February 13. Less than half an hour later, Hawley lowered Hubble onto the Flight Support System berthing platform in the cargo bay, where it was latched in place for its servicing.

The first of four space walks began at 10:34 p.m. CST on February 13, when mission specialists Mark Lee and Steve Smith switched their space suits over to battery power. Once outside, Lee and Smith spent 6 hours and 42 minutes upgrading HST. They removed the Goddard High Resolution Spectrograph and the Faint Object Spectrograph. The telephone-booth sized instruments slid out of their compartments and were replaced by two brand new instruments, the Space Telescope Imaging Spectrograph and the Near Infrared Camera and Multi-Object Spectrometer. With their work successfully completed, Lee and Smith returned to *Discovery*'s airlock at 5:17 a.m. CST, February 14.

The second space walk of the STS-82 mission was a 7 hour, 27 minute walk to replace and install several new engineering components to HST. Beginning at 9:25 p.m. CST on February 14, mission specialists Greg Harbaugh and Joe Tanner worked to replace a degraded Fine Guidance Sensor and a failed Engineering and Science Tape Recorder with new spares. The astronauts also installed a new unit known as the Optical Control Electronics Enhancement Kit, which further increased the capability of the new fine guidance sensor. As Harbaugh and Tanner neared the end of their work in the cargo bay, *Discovery*'s small maneuvering jets were fired for about 20 minutes to gently raise Hubble's altitude by about 1.8 nautical miles. The second space walk ended at 4:52 a.m. CST on February 15.

The third space walk began at 8:53 p.m. CST on February 15, as mission specialists Lee and Smith removed and replaced a Data Interface Unit which provides command and data interfaces between Hubble's data management system and other subsystems. They also replaced an old reel-to-reel style Engineering and Science Tape Recorder with a new digital Solid State Recorder (SSR) that will allow simultaneous recording and playback of data. The final task for Lee and Smith was the change out of one of four Reaction Wheel Assembly units that use spin momentum to move the telescope toward a target and maintain it in a stable position. Lee and Smith returned to *Discovery*'s airlock at 4:04 a.m. CST on February 16, completing a 7 hour 11 minute space walk.

Following the third space walk, *Discovery*'s small maneuvering jets were fired for the third time for about 20 minutes to gently raise Hubble's altitude.

The replacement and installation of all the science and engineering components for the HST were completed with the fourth space walk of the STS-82 mission. Mission Specialists Harbaugh and Tanner began their second walk by emerging from *Discovery*'s airlock at 9:45 p.m. CST, February 16. Their first task was the replacement of a Solar Array Drive Electronics package which is used to control the positioning of Hubble's solar arrays. Harbaugh and Tanner next ventured to the top of the telescope where they replaced covers over Hubble's magnetometers, which are used to sense the telescope's position in relation to the Earth through data acquired from the Earth's magnetic field. The astronauts then placed thermal blankets of multi-layer material over two areas of degraded insulation around the light shield portion of the telescope just below the top of the astronomical observatory.

Harbaugh and Tanner returned to the shuttle's airlock at 4:19 a.m. CST on February 17.

A fifth space walk was added to the flight plan because of Hubble managers' concerns about several separations in the external insulation on the observatory. The concern was that the separated areas could trap light and cause localized heating, damaging Hubble's sensitive systems.

During their final excursion in *Discovery*'s cargo bay, Mission Specialists Lee and Smith attached several thermal insulation blankets to three equipment compartments at the top of the Support Systems Module section of Hubble which contains key data processing, electronics and scientific instrument telemetry packages. The 5 hour, 17 minute space walk ended when mission specialists Mark Lee and Steve Smith reentered the airlock for the final time at 2:32 a.m. CST on February 18.

With all of the servicing tasks complete, Commander Bowersox and Pilot Horowitz fired small maneuvering jets for approximately 32 minutes to complete the reboost of the telescope, raising its orbit an additional three nautical miles.

Hawley, who first deployed Hubble during the STS-31 mission on April 25, 1990, again used the shuttle's robot arm to gently release the telescope at 12:41 a.m. CST on February 19. Shortly after deployment, payload controllers reported that the telescope had resumed standard operations and was processing commands from the ground through the Tracking and Data Relay Satellite system.

Commander Ken Bowersox and Pilot Scott Horowitz guided *Discovery* to a night landing at the Kennedy Space Center at 2:32 a.m. CST to end the almost 10-day flight in which four astronauts spent more than 33 hours walking in space.

Payload Descriptions

HUBBLE SCIENCE INSTRUMENTS

The Space Telescope Imaging Spectrograph (STIS): The STIS replaced the Goddard High Resolution Spectrograph (GHRS). It included all the major capabilities of both the current spectrographs, the GHRS and the Faint Object Spectrograph (FOS), and added new technological capability. The STIS optical design features internal corrective optics to compensate for the HST primary mirror spherical aberration.

STIS is an instrument that spans ultraviolet, visible, and near infrared wavelengths. It separates the light gathered by the telescope into its component colors allowing scientists to analyze the composition of celestial objects—their temperature, motion, and other chemical and physical properties.

STIS's main advance is its capability for two-dimensional rather than one-dimensional spectroscopy. STIS's two-dimensional detectors allow the instrument to gather 30 times more spectral data and 500 times more spatial data than existing spectrographs on Hubble, which look at one place at a time. This means that many regions in a planet's atmosphere or many stars within a galaxy can be recorded in one exposure making the HST faster and more efficient. One of the greatest advantages to using STIS is in the study of supermassive black holes.

STIS contains a new generation electronic light sensor called a Multi-Anode Microchannel Array (MAMA), as well as a Charge Coupled Device (CCD). STIS's coronograph allows it to search the environment of bright stars for very faint companion objects (possible planets). STIS also takes ultraviolet images like a camera, searches for massive black holes by studying the star and gas dynamics around galactic centers, measures the distribution of matter in the universe by studying quasar absorption lines, and uses its high sensitivity and ability to detect fine detail to study stars forming in distant galaxies. It can perform spectroscopic mapping—measuring chemical composition, temperature, gas density and motion across planets, nebulae and galaxies. The principal investigator for STIS was Goddard Space Flight Center, Greenbelt, MD. The prime contractor was Ball Aerospace Systems Group, Boulder, CO. Following installation and calibration, the operation of STIS was managed by the Space Telescope Science Institute, Baltimore, MD.

The Near Infrared Camera and Multi-Object Spectrometer (NICMOS): NICMOS replaced the Faint Object Spectrograph (FOS). Like STIS, NICMOS's design features corrective optics to compensate for HST's primary mirror spherical aberration. NICMOS provides the capability for infrared imaging and spectroscopic observations of astronomical targets. Its detectors perform much better than previous infrared detectors.

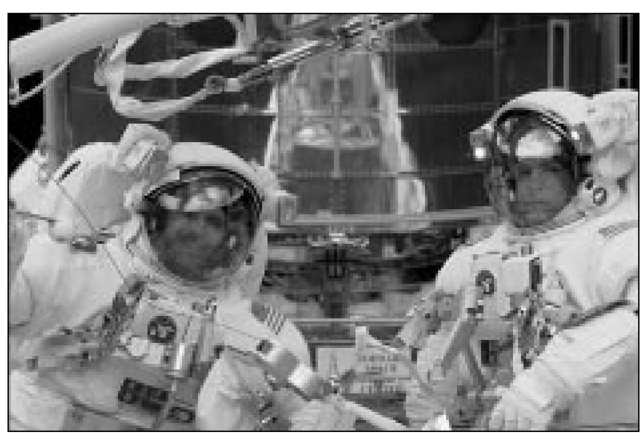
The expansion of the universe shifts the light from very distant objects toward longer red and infrared wavelengths. NICMOS's near infrared capabilities provide views of objects too distant for research by existing Hubble instruments which were sensitive only to optical and ultraviolet wavelength light.

NICMOS probes objects created near the beginning of the universe. It looks deeper into the clouds of dust to view how stars and planets are formed, and can see further back in time and farther away in distance. It detects cold objects such as brown dwarfs which emit light most brightly at infrared wavelength.

NICMOS is much more than a camera. It is also a spectrometer, a coronagraph and a polarimeter. Each of these operational modes is initiated by rotating the proper element in a wheel containing filters and optical components into the camera beam. A combination of grating and a prism, called a grism, provides spectroscopy for NICMOS. A set of polarizers in the wheel are rotated into place when observers want to determine the degree of polarization of radiation from a celestial object. One of the cameras has a special set of masks to block light from a bright object to observe an adjacent faint object, such as a faint planet near a bright star. This is called a coronagraph.

The sensitive infrared detectors in NICMOS must operate at very cold temperatures, 58 degrees Kelvin (minus 355 degrees Fahrenheit), because any heat from surroundings will create extra infrared signals that would interfere with the actual signal from the object being studied. NICMOS keeps its detectors cold inside a cryogenic dewar (a thermally insulated container) containing frozen nitrogen. The dewar cools the detectors for up to five years. NICMOS is HST's first cryogenic instrument.

The principal investigator for NICMOS was the University of Arizona



Astronauts Steven Smith (left) and Mark Lee face their crew mates, located in the shirt-sleeve environment of *Discovery*'s aft flight deck during a break from hands-on duty.

Astronaut Scott Horowitz at the pilot's station works with a hand-fashioned chord loop fastener device to be used in support of the additional STS-82 space walk to service HST. Sketches overhead were sent by ground controllers to guide the pilot's engineering task.

(UA) under contract with NASA's Goddard Space Flight Center (GSFC), Greenbelt, MD. The major subcontractors were Ball Aerospace Systems Group, Boulder, CO, and Rockwell International Corp., Thousand Oaks, CA. Following its installation and calibration, NICMOS was managed by the Space Telescope Science Institute, Baltimore, MD.

REPLACEMENT HARDWARE

Solid State Recorder (SSR): The (SSR) replaced one of HST's existing reel-to-reel recorders. The data management system of the HST includes three tape recorders to store engineering or science data that cannot be transmitted to the ground immediately. The SSR has no reels, no tape and no moving parts to wear out.

The SSR is about the same size as the reel-to-reel recorder, but it can store 10 times as much data in computer-like memory chips until HST's operators at GSFC command the SSR to play it back. The SSR stores 12 gigabits of data, while the tape recorder it replaces stores only 1.2 gigabits.

The Fine Guidance Sensors (FGSs) are one of five different types of sensors used by the HST's pointing control system to point the telescope at a target with an accuracy of 0.01 arcsecond (an arcsecond is 1/3600 of a degree). The guidance sensors lock on to a star and then measure any apparent motion to an accuracy of 0.0028 arcsec. This gives the HST the ability to remain pointed at that target with no more than 0.007 arcsec. of deviation over long periods of time. This level of stability is comparable to being able to hold a laser beam focused on a dime 200 miles away (about the distance from Washington, DC, to New York City).

FGSs also can be used for astrometry, which is the science that deals with determination of precise positions and motions of stars and other celestial objects. The FGSs can provide star positions that are about 10 times more precise than those observed from a ground-based telescope.

When used for astrometric science, the fine guidance sensors let the HST: search for the wobble in the motion of nearby stars which could indicate the presence of a planetary companion; determine if certain stars are really double stars; measure the masses of stars; measure the angular diameter of stars, galaxies, etc.; refine the positions and the absolute magnitude scale for stars; and help determine the true distance scale for the universe.

Reaction Wheel Assembly (RWA): One of Hubble's four RWAs was replaced with a refurbished spare. The RWA is part of Hubble's Pointing Control Subsystem. Spin momentum to the wheels moves the telescope toward a target and maintains it in a stable position.

Data Interface Units: Four Data Interface Units (DIU) on HST provide command and data interfaces between the spacecraft's data management system and the other HST subsystems. DIU-2 was replaced with a spare unit that has been modified and upgraded to correct for failures that occurred in the original unit.

Solar Array Drive Electronics (SADE): The SADE control the positioning of the solar arrays. HST has two SADEs. One unit was replaced during the first servicing mission. The unit that was returned from orbit was refurbished to correct for problems that resulted in transistor failures and was used to replace the second unit, SADE-2. The SADEs were provided by the European Space Agency.

Magnetic Sensing System (MSS): Work on the MSS on Hubble during the first servicing mission required the astronaut crew to construct protective covers for the hardware using materials that were available on the shuttle. Some of this material was degrading in the space environment and required the installation of more durable covers during the second servicing mission.

Engineering Science Tape Recorder (ESTR): The ESTR stores data onboard the telescope. There are three ESTRs onboard the HST. Engineering data are recorded during periods when no communications with the ground are scheduled. Science data are always recorded to prevent loss of data if an unplanned communications outage should occur. In normal operations, two ESTRs are used to record science and the third records engineering data when necessary. One of the ESTRs had failed and was replaced with an identical flight spare ESTR. Another ESTR was replaced with the Solid State Recorder.

Optical Control Electronics Enhancement Kit: The Optical Control Electronics Enhancement Kit is a cable that is used on the Optical Control Electronics box to reroute signals to send commands to move the new adjustable mirror that is internal to the Fine Guidance Sensor.

CREW AIDS AND TOOLS

The crew took more than 300 different crew aids and tools with them. These crew aids and tools, part of the Space Support Equipment (SSE) hardware, ranged from a simple bag for carrying some of the smaller tools to sophisticated, computer-controlled power tools.

Crew aids are fixed-in-place or portable equipment items, other than hand tools, used to assist crew members in accomplishing servicing mission tasks. Crew aids permit the astronauts to maneuver safely or to anchor themselves in one location while working in the weightlessness of space. They also help in moving Orbital Replacement Units (ORUs) and Scientific Instruments (SIs), protect equipment and crew during the change out activities, and provide temporary stowage of equipment during Extra-vehicular Activities (EVAs). Examples of crew aids are: handrails, handholds, transfer equipment, protective covers, tethering devices, grapple fixtures, foot restraints, and stowage and parking fixtures.

Tools are hand-operated devices that allow EVA astronauts to more efficiently perform intricate, labor-intensive tasks. Tools allow the crew to access equipment bays on both the spacecraft and the shuttle, and to remove and install ORUs and SIs.

Among the tools carried aboard STS-82 for HST servicing were: the power ratchet tool, the multisetting torque limiter, adjustable extensions with 7/16-inch sockets, a newly developed computer-controlled pistol grip tool, and a series of new connector tools. Spares of all the tools were carried on the shuttle to ensure the success of the mission and safety of the crew.

Power Ratchet Tool (PRT): The power ratchet tool is powered by a 28-volt battery. Made of titanium and aluminum, the 17-inch (43 cm) tool was used for tasks requiring controlled torque, speed or turns, and can be used where right-angle access is required.

Multisetting Torque Limiter (MTL): This tool was provided to prevent damage to hardware due to the application of torque which may exceed design limits. Multisetting torque limiters are used in conjunction with the power tools or hand tools that interface with bolts and latches on the telescope.

Adjustable Extensions: Two extensions were designed to be adjustable, allowing astronauts to move more easily and efficiently.

Pistol Grip Tool (PGT): This unique ratchet tool was designed for use by the astronauts during EVA activities. The experiences of crew members on HST's first servicing mission led to recommendations for a smaller, more efficient tool for precision work in a space environment. The PGT is a self-contained, micro-processor controlled, battery-powered, hand-held tool. It also can be used as a non-powered ratchet wrench. The PGT's micro-processor can be programmed to control limits for torque, speed, and number of turns.

The tools and crew aids were stowed on or in the Solar Array Carrier (SAC), Orbital Replacement Unit Carrier (ORUC), Flight Support System (FSS), sidewall-mounted adapter plates, Tool Stowage Assembly (TSA), an Adaptive Payload Carrier (APC), middeck lockers, aft flight-deck and airlock. Tools and crew aids were provided by Johnson Space Center and Goddard Space Flight Center.

CREW BIOGRAPHIES

Commander: Kenneth D. Bowersox (Cmdr, USN). Bowersox, 40, was born in Portsmouth, VA, but considers Bedford, IN, to be his hometown. He graduated from Bedford High School., received a bachelor of science degree in aerospace engineering from the United States Naval Academy, and a master of science degree in mechanical engineering from Columbia University.

Bowersox was selected as an astronaut candidate by NASA in June 1987. He flew as pilot on STS-50 in 1992 and STS-61 in 1993, and was the spacecraft commander on STS-73 in 1995. With the completion of STS-82 he has logged more than 1,200 hours in space.

Pilot: Scott J. "Doc" Horowitz, Ph.D. (Lt. Col., USAF). Horowitz, 39, was born in Philadelphia, PA, but considers Thousand Oaks, CA, to be his hometown. He graduated from Newbury Park High School, Newbury Park, CA, received a bachelor of science degree in engineering from California State University at Northridge, a master of science and doctorate degrees in aerospace engineering from Georgia Institute of Technology.

He was selected for the astronaut program in March 1992 and served as pilot on STS-75 in 1996. With the completion of STS-82, Horowitz had logged more than 617 hours in space.

Mission Specialist: Joseph R. "Joe" Tanner. Tanner, 47, was born in Danville, IL. He graduated from Danville High School, and received a bachelor of science degree in mechanical engineering from the University of Illinois.

Selected as an astronaut candidate by NASA in March 1992, Tanner reported to the Astronaut Office in

In-flight portrait. Front row, left to right: Joseph Tanner, Mark Lee and Gregory Harbaugh. Back row, left to right: Steven Hawley, Kenneth Bowersox and Scott Horowitz. Top of frame, Steven Smith.

STS-82
Quick Look

Launch Date: Feb. 11, 1997
Time: 2:55 a.m. CST
Site: KSC Pad 39A

Orbiter: *Discovery*
OV-103—18th flight

Orbit/In.: 160 naut. miles
313 nm for docking
28.45 degrees

Mission Duration: 9 days, 23 hrs, 37 mns.

Landing Date: Feb. 21, 1997
Time: 2:32 a.m. CST
Site: Kennedy Space Center

Crew: Ken Bowersox, (CDR)
Scott Horowitz, (PLT)
Joe Tanner, (MS1)
Steve Hawley, (MS2)
Gred Harbaugh, (MS3)
Mark Lee(MS4-)
Steve Smith (MS5)

Cargo Bay Payloads: HST Second Servicing Mission
Flight Support System
Orbital Replacement Unit Carrier
Second Axial Carrier

STS-82 is the second mission to service the Hubble Space Telescope (HST). The central feature of the patch is the Hubble Space Telescope as the crew will see it through *Discovery'*s overhead windows as the Orbiter approaches for rendezvous, retrieval and subsequent extravehicular activity (EVA) servicing tasks. The HST is pointing toward deep space, observing the cosmos. The spiral galaxy symbolizes one of HST's important scientific missions, to accurately determine the cosmic distance scale. To the right of the HST is a cross-like structure known as a gravitational lens, one of the numerous fundamental discoveries made using HST imagery. The names of the STS-82 crew members are arranged around the perimeter of the patch with the EVA crew members placed in the upper semicircle and the orbiter crew in the lower.

August 1992. He flew aboard the Space Shuttle *Atlantis* on STS-66, and with the completion of STS-82 had logged more than 502 hours in space including more than 14 hours of EVA.

Mission Specialist: Steven A. Hawley (Ph.D.). Hawley, 45, was born in Ottawa, KS, but considers Salina, KS, to be his hometown. Hawley graduated from Salina (Central) High School, received a bachelor of arts degrees in physics and astronomy (graduating with highest distinction) from the University of Kansas, and a doctor of philosophy in astronomy and astrophysics from the University of California.

Hawley was selected as a NASA astronaut in January 1978 and served as a mission specialist on three flights—STS-41D in 1984, STS-61C in 1986, and STS-31 in 1990. In June 1990, Hawley left the Astronaut Office to assume the post of Associate Director of NASA's Ames Research Center in California. In August 1992, Hawley returned to the Johnson Space Center as Deputy Director of Flight Crew Operations. In February 1996, Hawley was returned to astronaut flight status and named to the crew of the second Hubble Space Telescope servicing mission. With the completion of STS-82, Hawley had logged more than 652 hours in space.

Mission Specialist: Gregory J. Harbaugh. Harbaugh, 40, was born in Cleveland, OH. Willoughby, OH, is his hometown. Harbaugh graduated from Willoughby South High School, received a bachelor of science degree in aeronautical and astronautical engineering from Purdue University, and a master of science degree in physical science from University of Houston-Clear Lake.

Harbaugh was selected as an astronaut by NASA in June 1987. He flew on three previous shuttle flights as a mission specialist—STS-39 in 1991, STS-54 in 1993, and STS-71 in 1995. With the completion of his fourth flight, Harbaugh had logged more than 818 hours in space including more than 18 hours of EVA.

Mission Specialist: Mark C. Lee (Col., USAF). Lee, 44, was born in Viroqua, WI. He graduated from Viroqua High School, received a bachelor of science degree in civil engineering from the U.S. Air Force Academy, and a master of science degree in mechanical engineering from Massachusetts Institute of Technology.

Lee was selected as an astronaut candidate by NASA in May 1984. Lee flew on STS-30 in 1989, STS-47 in 1992, and STS-64 in 1994. With the completion of STS-82, Lee had logged more than 790 hours in orbit including more than 26 hours of EVA.

Mission Specialist: Steven L. Smith. Smith, 38, was born in Phoenix, AZ, but considers San Jose, CA, to be his hometown. Smith graduated from Leland High School in San Jose, received a bachelor of science degree in electrical engineering from Stanford University, a master of science degree in electrical engineering from Stanford University, and a master's degree in business administration from Stanford University.

Smith was selected as an astronaut candidate by NASA in March 1992, and flew on mission STS-68 in 1994. With the completion of STS-82, Smith had logged more than 509 hours in space including more than 19 hours of EVA.